

Climate and Health Vulnerability Assessment Indicators

AIR QUALITY

BUILT ENVIRONMENT UNIT- CLIMATE PROGRAM

*HCPH is the local public health agency for the Harris County, Texas jurisdiction.
It provides a wide variety of public health activities and services aimed at improving the health and well-being of the Harris County community.*

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Ozone

Indicator Title: Ozone Concentration

Indicator Description: Average Daily Ozone Values by census tract from 2012 to 2019

Assessment Group: Exposure

Summary of evidence for Climate and Health: Ground level ozone is formed from the reaction between nitrogen oxides (NO_x), volatile organic compounds (VOC), and sunlight. Ground level ozone production occurs more in the summer when temperatures are higher. This is a concern because in many areas the summer season is getting longer (Knowlton et. al, 2004). Ozone is an oxidant and can inflame and damage airway passages (Zhang et al, 2019). The respiratory system is impacted with both short term and long-term exposures. Short-term exposures can lead to difficulty taking deep breaths and exacerbation of asthma and other respiratory diseases. In addition to the short-term impacts, long term exposure may cause the development of asthma and other respiratory diseases (U.S. EPA, 2015). Taking both climate change and population changes into account, one study found a 59.9% increase in ozone related deaths in New York City Region in the 2050's (Knowlton et. al, 2004).

What is the indicator: Average Daily Ozone concentration values by census tract from 2012 to 2019

Data Source and methodology: A Bayesian space-time downscaler model is used to "fuse" daily ozone (8-hr max) monitoring data from the National Air Monitoring Stations/State and Local Air Monitoring Stations (NAMS/SLAMS) with 12 km gridded output from the Models-3/Community Multiscale Air Quality (CMAQ) model.

<https://www.epa.gov/hesc/rsig-related-downloadable-data-files>

Limitations: This indicator uses average values; some parts of the day may have higher or lower concentrations.

References

Knowlton, K., Rosenthal, J. E., Hogrefe, C., Lynn, B., Gaffin, S., Goldberg, R., Rosenzweig, C., Civerolo, K., Ku, J. Y., & Kinney, P. L. (2004). Assessing Ozone-Related Health Impacts under a Changing Climate. *Environmental Health Perspectives*, 112(15), 1557–1563.
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PM2.5

Indicator Title: PM2.5 Concentration

Indicator Description: Average Daily PM2.5 Values by census tract from 2012 to 2019

Assessment Group: Exposure

Summary of evidence for Climate and Health:

Exposure to PM_{2.5} is associated with negative health effects in the US population. PM_{2.5} exposure increases overall mortality and reduces life expectancy (Bennett et al., 2019). Studies have shown that exposure to wildfire produced PM_{2.5} increases respiratory and chronic obstructive pulmonary disease (COPD) mortality in the days following wildfire events (Doubleday et al., 2020). Obesity and weight gain are also associated with PM_{2.5} exposures, even at levels below the 2012 National Ambient Air Quality Standard (Bowe et al., 2021). As policy has changed and actions have been taken to reduce PM_{2.5} exposure, there has been an associated decrease in cardiovascular mortality rates (Peterson et al., 2020). Localities that have reduced PM_{2.5} producing power generation sources, have seen increases in child health benefits and child health outcomes (Perera et al., 2020).

What is the indicator: Average Daily PM_{2.5} Values by census tract from 2012 to 2019

Data Source and methodology: A Bayesian space-time downscaler model is used to "fuse" fine particulate air (24-hr average) monitoring data from the National Air Monitoring Stations/State and Local Air Monitoring Stations (NAMS/SLAMS) with 12 km gridded output from the Models-3/Community Multiscale Air Quality (CMAQ) model.

<https://www.epa.gov/hesc/rsig-related-downloadable-data-files>

Limitations: This indicator uses average values; some parts of the day may have higher or lower concentrations.

References:

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Respiratory Conditions

Indicator Title: Respiratory Conditions

Indicator Description: Percentage of adults with asthma and/or COPD

Assessment Group: Sensitivity

Summary of evidence for climate and health

Particulate matter, ozone, sulfur dioxides, and nitrogen dioxides are common outdoor air pollutants that exacerbate respiratory conditions such as asthma, COPD, and lung cancer. However, there are many more air pollutants such as benzene and lead that are also a concern. Air pollution such as particulate matter reduces lung function for people with COPD and other respiratory conditions. High levels of air pollution often increase emergency department visits, hospital admissions, and mortality for those with COPD (Jiang, Mei & Feng, 2016). Air pollution can affect asthma prevalence, onset, symptoms, and the reaction to treatment. Air quality plays an important role in the inception of asthma early in life and later a trigger of asthma exacerbations (Zhang, Wei, & Fang 2019). Pollen is a concern during certain seasons and as temperatures increases contributes to air pollution and can exacerbate asthma and other respiratory conditions (Anderson et al., 2013).

What is the indicator: Percentage of adults who have had an asthma and/or COPD diagnosis

Data Source and methodology: These estimates come from the 2018 Health of Houston Survey by the University of Texas School of Public Health. <https://sph.uth.edu/research/centers/ihp/#TID-e1bc0d84-d308-4213-9931-c667967d8c23-3>. The percentage estimates of Respiratory Disease were calculated as the sum of those who have ever had an Asthma diagnosis, a COPD diagnosis or both. This data was provided at the PUMA level. PUMAs are larger than census tracts. Each census tract was assigned the value associated with the PUMA in which it is located.

Limitations: This data is at PUMA level and may not completely or accurately represent the percentage of respiratory conditions at the census track level.

References

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Cardiovascular Disease

Indicator Title: Cardiovascular Disease

Indicator Description: Percentage of adults with cardiovascular disease

Assessment Group: Sensitivity

Summary of evidence for climate and health: Recent research has found that particulate matter (PM) and nitrogen oxides (NO_x) near the National Ambient Air Quality Standards can cause blood vessels to age early and cause calcium to build up in the coronary artery which increases the probability of strokes and heart attacks (Kaufman Et al , 2016). Exposure to air pollution can increase the build-up of plaque in arteries, which over time can increase risk of cardiovascular disease (EPA 2022).

What is the indicator: Percentage of adults who have had a diagnosis of coronary heart disease

Data Source and methodology: These estimates come from the 2018 Health of Houston Survey by the University of Texas School of Public Health. <https://sph.uth.edu/research/centers/ihp/#TID-e1bc0d84-d308-4213-9931-c667967d8c23-3>. This data was provided at the PUMA level. PUMAs are larger than census tracts. Each census tract was assigned the value associated with the PUMA in which it is located.

Limitations: This data is at PUMA level and may not completely or accurately represent the percentage of cardiovascular disease at the census track level.

References

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Poverty

Indicator Title: Households Living Below the Poverty Line

Indicator Description: Percentage of population living below the poverty line

Assessment Group: Sensitivity

Summary of evidence for climate and health

Studies have shown that poverty and socioeconomic status (SES) play a role in people's exposure to air pollution. Exposure to air pollutants such as ozone and PM_{2.5} have negative effects on health and those in lower SESs may be more likely to experience those negative health effects. Those in higher SESs are more likely and able to move away from highly polluted areas (Larr et al., 2016). Lower income groups are more likely to live in an area with higher exposure to air pollution in the United States. (Clark et al., 2017). Neighborhood SES may be an indicator to determine the likelihood of exposure to air pollutants as well as the likelihood of associated negative health effects (Chi et al., 2016; Lenick et al., 2017).

What is the indicator: Percentage of population living below the poverty line

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percentage of families and people whose income in past 12 months is below the poverty level (DP03_0128PE)

Limitations:

References:

- Chi, G. C., Hajat, A., Bird, C. E., Cullen, M. R., Griffin, B. A., Miller, K. A., Shih, R. A., Stefanick, M. L., Vedal, S., Whitsel, E. A., & Kaufman, J. D. (2016). *Individual and Neighborhood Socioeconomic Status and the Association between Air Pollution and Cardiovascular Disease*. *Environmental Health Perspectives*, 124(12), 1840–1847. <https://doi.org/10.1289/EHP199>
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Linguistic Barriers

Indicator Title: Limited English-speaking abilities

Indicator Description: Percent of population with limited English proficiency

Assessment Group: Sensitivity

Summary of evidence for climate and health

There are several reasons why linguistic barriers have been identified as a risk factor for the health impacts of air pollution. The ability to access information and knowledge is important in preparation for hazards and in response and recovery to hazardous events (Gares and Montz, 2014). People that speak limited English may not fully understand typical air quality warnings and public health messaging presented in English. During chemical fires or industrial events communication method and language inclusivity is important. During the BP oil spill Vietnamese fisherman struggled to access information because it was primarily available online and they did not have access to a computer. Additionally, the information was primarily in English, and they spoke Vietnamese. A language barrier can inhibit the ability to navigate government claims, loans, and regulations to address issues associated with disasters. (Grossman and Mark, 2010). If a health emergency were to occur, language barriers can often delay medical care if healthcare providers are unable to communicate. A language barrier can feel isolating and similar to social isolation, it can hinder people from seeking help during extreme heat events or other emergencies (Hansen et al., 2014).

What is the indicator: Percentage of the population that speaks English less than well

Data Source and methodology: Harris County ACS 2019 5 year profile estimates by Census Tract, percent of the population greater than 5 years old that speaks English less than well (DP02_0113PE)

Limitations:

References:

Gares, C. E., & Montz, B. E. (2014). Disaster Vulnerability of Migrant and Seasonal Farmworkers: A Comparison of Texas and North Carolina. *Southeastern Geographer*, 54(1), 36–54. <https://doi.org/10.1353/sgo.2014.0000>

Grossman, E., & Mark, J. (2010). DISASTER in Another Language. *Earth Island Journal*, 25(3), 38–39.

Hansen, A., et al., *Extreme heat and cultural and linguistic minorities in Australia: perceptions of stakeholders*. 2014. 14(1): p. 550.

Race and Ethnicity

Indicator Title: Population of Color

Indicator Description: Percent of population that identify as black, indigenous, people of color, and/or Hispanic.

Assessment Group: Sensitivity

Summary of evidence for climate and health

The adverse impacts of air pollution on health are well known. Communities of color in the United States are disproportionately impacted by the effects of air pollution. Air pollution exposures are higher for communities of color when compared to non-minority populations. One study found that for all six of the EPA criteria pollutants the most exposed group was a minority group (Jaiwen et al., 2021). Even though air pollution in the US has decreased over time, communities of color are still the most exposed to higher levels of air pollution (Clark et al., 2017).

What is the indicator: Percent of the population that is not non-Hispanic white

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract
Calculated: $(\text{Total Population}[\text{DP05_0033E}] - \text{Count Non-Hispanic White alone}[\text{DP05_0077E}]) / \text{Total Population}[\text{DP05-0033E}] * 100$

Limitations: For the purposes of this assessment the racial and ethnic groups identified were assumed to have equal vulnerability; however, there may be variation in the level of vulnerability among these different groups.

References

Clark, L. P., Millet, D. B., & Marshall, J. D. (2017). Changes in Transportation-Related Air Pollution

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No Health Insurance

Indicator Title: No health insurance

Indicator Description: Percent of population without health insurance

Assessment Group: Sensitivity

Summary of evidence for climate and health: Health insurance is an important component to consider when thinking about any health outcomes that require medical care. Air pollution impacts the respiratory system, as discussed previously, in addition, it can also impact the cardiovascular system, nervous system, and immune system. Poor air quality exacerbates certain health conditions, like asthma, COPD and cardiovascular disease which can lead to increases in hospitalizations and need for medical care and medications (Jiang, Mei & Feng, 2016). Studies have shown that populations without health insurance are less likely to seek health care, and if they do receive care will likely have the added stress of health care costs (Freeman et al., 2008). Additionally, people without health insurance were less likely to receive care for critical issues compared to those with insurance (Fowler et al., 2010).

What is the indicator: Percent of population without health insurance

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percent of civilian noninstitutionalized population with no health insurance coverage (DP03_0099PE)

Limitations:

References:

Fowler RA, Noyahr L, Thornton D, et al. An Official American Thoracic Society Systematic Review: The Association between Health Insurance Status and Access, Care Delivery, and Outcomes for Patients Who Are Critically Ill. *American Journal of Respiratory and Critical Care Medicine*. 2010; 181: 1003-1011

Freeman JD, Kadiyala S, Bell JF, et al. The causal effect of health insurance on utilization and outcomes in adults: A systematic review of US studies. *Med Care*. 2008; 46(10): 1023-32.

Jiang, X. Q., Mei, X. D., & Feng, D. (2016). Air pollution and chronic airway diseases: what should people know and do. *Journal of thoracic disease*, 8(1), E31–E40.
<https://doi.org/10.3978/j.issn.2072-1439.2015.11.50>

Outdoor workers

Indicator Title: Outdoor workers

Indicator Description: Percent of employed population that work outdoors

Assessment Group: Sensitivity

Summary of evidence for climate and health:

Outdoor workers spend their workdays outdoors and exposed to the elements of the localities in which they work. In addition to having increased weather-related exposures such as heat, outdoor workers may have increased pollution related exposures which may negatively impact their health. Outdoor workers spend the majority of their workday breathing in the ambient air which increases their exposure to pollutants in the air. The previous sections have highlighted the negative health impacts of air pollution exposure, particularly ozone and PM_{2.5}. Type of outdoor work, location, and weather conditions may also impact the extent of exposure (NIOSH, 2022).

What is the indicator: Percentage of employed population that works outdoors

Data Source and methodology: Harris County ACS 2019 5-year subject table estimates by Census Tract , Calculated: (Farming, Fishing, Forestry Occupations [S2401_C01_030E] + Construction and Extraction Occupations [S2401_01_031E]) / Total employed population > 16 years [S2401_C01_001E] * 100

Limitations: The categories selected were chosen because these fields are likely to have a high percentage of outdoor workers. There may be outdoor occupations missed and similarly this could entail some workers that do not primarily work outside.

References:

Impact of Climate on Workers / NIOSH / CDC. (2022, March 18).

<https://www.cdc.gov/niosh/topics/climate/how.html>

Children

Indicator Title: Children under 18

Indicator Description: Population 0-18 years of age

Assessment Group: Sensitivity

Summary of evidence for climate and health: Poor air quality can be extremely detrimental to children's health. World Health Organization (WHO) estimates that 600,000 children died in 2016 from acute lower respiratory infections as a result of exposure to air pollution (WHO 2018). Exposure to air pollution can begin in utero and continue throughout the child's life. Children's lungs, central nervous system, and brain are still developing which puts them at greater risk for adverse health outcomes. Additionally, children breathe faster than adults, so they are exposed to greater amounts of pollutants (Brumberg et.al, 2021; WHO, 2018) Pregnant women exposed to high levels of indoor and/or outdoor air pollution are more likely to deliver prematurely, and babies can be born at low birth weights (Bekkar et al, 2020; Brumberg et. al, 2021; WHO, 2018) Exposure to air pollution, particularly traffic-related pollutants, in utero can impact neurodevelopmental disorders in children (Brumberg et al, 2021). The

mother's exposure to nitrogen dioxide (NO₂) during pregnancy can impact adolescent behavioral issues. In children 2-4 years of age, exposure to PM_{2.5} was associated with poor cognitive performance. Behavioral and cognitive issues can impact children far beyond childhood. It can impact academic achievement, substance abuse, depression, and decreased economic prosperity (Ni et al, 2022). Inhalation of air pollutants puts the lungs and respiratory system at risk. Air pollutants, such as ozone, NO_x, and PM have all been shown to impact asthma prevalence and/or exacerbation of asthma symptoms. Increased doctor visits and school absences are an indirect effect of childhood asthma complications. Childhood leukemia has also been associated with NO₂ and Benzene (Brumberg and Karr, 2021).

What is the indicator: Percentage of population age 0-18.

Data Source and methodology: Harris County ACS 2019 5 year profile estimates by Census Tract, percentage of population under 18 years old (DP05_0005PE)

Limitations:

References:

Bekkar, B., Pacheco, S., Basu, R., & DeNicola, N. (2020). Association of Air Pollution and Heat Exposure With

Preterm Birth, Low Birth Weight, and Stillbirth in the US: A Systematic Review. *JAMA Network Open*, 3(6), e208243. <https://doi.org/10.1001/jamanetworkopen.2020.8243>

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Yu Ni, Loftus, C. T., Szpiro, A. A., Young, M. T., Hazlehurst, M. F., Murphy, L. E., Tylavsky, F. A., Mason, W. A.,

LeWinn, K. Z., Sathyanarayana, S., Barrett, E. S., Bush, N. R., & Karr, C. J. (2022). Associations of Pre- and Postnatal Air Pollution Exposures with Child Behavioral Problems and Cognitive Performance: A U.S. Multi-Cohort Study. *Environmental Health Perspectives*, 130(6), 067008–1. <https://doi.org/10.1289/EHP10248>

Proximity to Industry

Indicator Title: Proximity to Industrial facilities

Indicator Description: Percent of census tract land area within ½ mile of an Industrial Facility

Assessment Group: Sensitivity

Summary of evidence for climate and health:

People living near industrial operations are more likely to be exposed to sources of pollutants and environmental toxics than those that do not (Spencer-Hwang et al, 2014). Exposure to these pollutants can have negative impacts on health and worsen the severity of existing health conditions. Exposure to industrial toxics tend to be higher for all population subgroups in areas where there is a large discrepancy between the socioeconomic situations of its residents. (Ash et al, 2013). Low-income and minority residents are more likely to live in areas with sources of industrial exposures that may negatively impact their health (Ard et al, 2017). They experience greater health disparities which may be exacerbated by living in areas which are more likely to be located near an industrial source of pollution.

What is the indicator: Proximity to Industry

Data Source and methodology: Percent of land area within ½ mile of an Industrial Facility

The EPA's Facility Registry Service (FRS) dataset was filtered for currently active facilities located within a mile of the Harris County border. Currently active facilities were defined as those having a FRS Status that was not N, Terminated, Permanently Closed, Expired, D, Inactive, Closed, or Permanently Shutdown. This definition includes ambiguous facilities that have a blank or unknown FRS status. Active facilities were further filtered by EPA program enrollment to include only those in the Emissions Inventory System (EIS), the National Pollutant Discharge Elimination System Integrated Compliance Information System (NPDES-ICIS) and the Risk Management Program (RMP). The large number of NPDES-ICIS facilities were further filtered to include only major dischargers. This finalized dataset of active EIS, RMP and NPDES-ICIS Major facilities was used to create half mile buffers around each facility, which was then used to calculate the percent of land area within the buffer for each census tract.

Limitations: The points included in the EPA FRS dataset may include discharge locations, facility center points or office locations. The dataset is a live service and may be updated by the EPA at any time, more information about the source dataset can be found at <https://www.epa.gov/frs>.

References:

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- Spencer-Hwang, R., Montgomery, S., Dougherty, M., Valladares, J., Rangel, S., Gleason, P., & Soret, S. (2014). Experiences of a Rail Yard Community: Life Is Hard. (Cover story). *Journal of Environmental Health*, 77(2), 8–17.

Proximity to High Traffic Roadways

Indicator Title: Proximity to high traffic roadways

Indicator Description: Percent of land area within 500 meters of roads with an AADT of 25,000 or more

Assessment Group: Sensitivity

Summary of evidence for climate and health:

Automobiles that utilize diesel or gasoline emit various air pollutants, such as CO, CO₂, VOCs, NO_x, PM, and hydrocarbons. Heavy traffic and traffic congestion have been linked to higher morbidity and mortality for drivers, commuters, and communities near these major thoroughfares. Roadways with a lot of traffic and congestion can lead to high concentrations of air pollutants because of increases in emissions due to the start, stop, and idling of vehicles. Decreased dispersion of pollutants also occurs during traffic congestion (Zhang and Batterman, 2013). Additionally, location to traffic and gas stations has been associated with childhood leukemia (Brumberg and Karr, 2021).

What is the indicator: Percent of high traffic roadways per census tract.

Data Source and methodology:

https://geo.dot.gov/server/rest/services/Hosted/Texas_2018_PR/FeatureServer/0

A 500 meter buffer was created around roads that had a AADT (Average Annual Daily Traffic) of 25,000 or greater. The percentage of land area within the buffer was then calculated for each census tract.

Limitations: The AADT was calculated by the US Department of Transportation Federal Highway Administration. The dataset is a live service and may be updated at any time, more information about the source dataset can be found here:

<https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm>

References:

Brumberg, H. L., Karr, C. J., Bole, A., Ahdoot, S., Balk, S. J., Bernstein, A. S., Byron, L. G., Landrigan, P. J., Marcus, S. M., Nerlinger, A. L., Pacheco, S. E., Woolf, A. D., Zajac, L., Baum, C. R., Campbell, C. C., Sample, J. A., Spanier, A. J., Trasande, L., & COUNCIL ON ENVIRONMENTAL HEALTH. (2021). Ambient Air Pollution: Health Hazards to Children. *Pediatrics*, 147(6), e2021051484. <https://doi.org/10.1542/peds.2021-051484>

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Older Adults

Indicator Title: 65+ Years of Age

Indicator Description: Population greater than 65 years of age

Assessment Group: Sensitivity

Summary of evidence for climate and health:

Exposure to climate related air pollution (PM_{2.5}, NO_x, Ozone) has an adverse impact on the population aged 65 and older. As their exposure to climate related air pollution increases, morbidity and mortality may increase as well. Studies have found that increased elderly exposure to PM_{2.5} is associated with increased hospital admissions for deep vein thrombosis and pulmonary embolism (Kloog et al. 2015). Exposure to NO₂ increases risk of cardiovascular and respiratory mortality. Elderly minorities may be at an increased risk of exposure to NO₂ and this exposure may be even greater for those living in rural areas. NO₂ is a primary component of ozone. Ground level ozone concentrations increase as outdoor

temperature increases (Clark et al. 2014). One study found that increased exposure to ozone was associated with increased overall mortality in the elderly population. The percentage of mortality was greater in non-urban areas compared to urban areas (Madrigano et al. 2015).

What is the indicator: Percentage of population aged 65 years or older

Data Source and methodology: Harris County ACS 2019 5-year profile estimates by Census Tract, percentage of population 65 years or older (DP05_0024PE)

Limitations:

References:

Clark, L. P., Millet, D. B., & Marshall, J. D. (2014). National Patterns in Environmental Injustice and Inequality: Outdoor NO₂ Air Pollution in the United States. PLoS ONE, 9(4), 1–8.

<https://doi.org/10.1371/journal.pone.0094431>

Kloog, I., Zanobetti, A., Nordio, F., Coull, B. A., Baccarelli, A. A., & Schwartz, J. (2015). Effects of airborne fine particles (PM_{2.5}) on deep vein thrombosis admissions in the northeastern United States. Journal of Thrombosis & Haemostasis, 13(5), 768–774. <https://doi.org/10.1111/jth.12873>

Madrigano, J., Jack, D., Anderson, G. B., Bell, M. L., & Kinney, P. L. (2015). Temperature, ozone, and mortality in urban and non-urban counties in the northeastern United States. Environmental Health: A Global Access Science Source, 14(1), 41–60. <https://doi.org/10.1186/1476-069X-14-3>

Access to Public Transit

Indicator Title: Access to public transportation

Indicator Description: Percent of Census Tract within a ½ mile walking distance of a public transportation stop

Assessment Group: Sensitivity

Summary of evidence for climate and health: Because transportation accounts for 27 percent of all U.S. greenhouse gas emissions reduction of cars and trucks can impact air pollution and climate change (U.S. EPA, 2015). Buses and trains with well planned route networks can provide alternatives for commuting and reduce the number of personal vehicles on the roads. Fewer personal vehicles can lead to less roadway congestion and a reduction of emissions. Use of public transit also promotes more walking which can benefit health.

What is the indicator:

Data Source and methodology: Houston Metro Bus Stops:

<https://mycity2.houstontx.gov/pubgis02/rest/services/HoustonMap/Transportation/MapServer/9>

Houston Metro Light Rail Stations:

<https://services3.arcgis.com/5y1dsBktpYbLnFYi/ArcGIS/rest/services/LRTStations/FeatureServer/0>

Harris County Transit Bus Stops:

https://services3.arcgis.com/5y1dsBktpYbLnFYi/arcgis/rest/services/CSD_HCT_Stops_20200824/FeatureServer

Harris County Parks: Harris County GIS Repository

City of Houston Parks:

<https://mycity2.houstontx.gov/pubgis02/rest/services/HoustonMap/Neighborhood/MapServer/14>

Harris County Bus Stops, Houston Metro Bus Stops and Houston Metro Light Rail Stations were combined into a single layer of public transportation stops. Stops within 50 meters of each other were consolidated into a single stop with the ESRI Integrate (Data Management) and Collect Events Tools. Consolidated stops were generally multiple stops at the same intersection. ESRI Network Analysis was used to create the 0.5 mile walking distance from the consolidated public transportation points.

Because there are several large parks in the Houston area that are over a mile wide, park land area was removed from both the 0.5 mile walking area and the total land area. This prevented lower scores for census tracts where otherwise good residential and commercial public transportation coverage did not penetrate into the interior of these large parks. The percentage of remaining land area within the 0.5 mile walking area was then calculated for each census tract.

Limitations:

References:

US EPA, O. (2015, September 10). *Carbon Pollution from Transportation* [Overviews and Factsheets].

<https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation>

Electric Vehicle Charging Stations

Indicator Title: Electric car charging accessibility

Indicator Description: Accessibility of each census tract to public electric vehicle (EV) charging stations

Assessment Group: Sensitivity

Summary of evidence for climate and health: Another method of reducing transportation emissions is the transition to electric vehicles. Electric vehicles (EVs) produce fewer emissions both directly from energy generation and indirectly from supply chain emissions (Wolfram et al, 2021). For electric vehicles to be used effectively there needs to be access to charging stations especially for EVs with shorter driving range.

What is the indicator: Driving time in minutes to the nearest charging station from the census tract centroid

Data Source and methodology:

https://afdc.energy.gov/fuels/electricity_locations.html#/analyze?fuel=ELEC

Electric fuel locations with one or more charging stations were downloaded from the Alternative Fuels Data Center and filtered for public locations in Harris County. ESRI's Network Analysis tool was used to calculate the driving time in minutes from census tract centroids to the nearest Charging Station.

Limitations: The Alternative Fuels Data Center updates its data on an ongoing basis. More information about their updating schedule and data collection and verification methods can be found on their website, link provided above.

References:

Wolfram, P., Weber, S., Gillingham, K., & Hertwich, E. G. (2021). Pricing indirect emissions accelerates low—Carbon transition of US light vehicle sector. *Nature Communications*, 12(1), 7121.
<https://doi.org/10.1038/s41467-021-27247-y>

Tree Canopy

Indicator Title: Tree canopy coverage

Indicator Description: Percentage of tree canopy coverage

Assessment Group: Adaptive Capacity

Summary of evidence for climate and health:

Trees can impact air quality in several different ways. Trees remove gaseous pollutants directly from the air. SO₂, NO₂, CO, and ozone can all be absorbed by trees (U.S. NPS, 2022). Particle pollution can settle out of air onto leaves and branches; however the wind can disperse these particles into the air again or rain can wash the particles from the tree surfaces. Tree Canopy provides natural shade and reduce the temperature of surrounding areas. Shaded houses and buildings require less air conditioning to maintain a comfortable temperature and therefore require less energy generation (Nowak & Heisler, 2010).

What is the indicator: Percentage of land area with tree canopy cover

Data Source and methodology: Tree Canopy data was obtained from the 2016 U.S. Geological Survey (USGS) National Land Cover Database (NLCD) at <https://www.mrlc.gov/data/type/tree-canopy>. The original 30 by 30-meter raster was converted to points and averaged by Census Tract.

Limitations:

References:

Air Pollution Removal by Urban Forests (U.S. National Park Service). (n.d.). Retrieved August 17, 2022, from <https://www.nps.gov/articles/000/uerla-trees-air-pollution.htm>

Nowak, D. J., & Heisler, G. M. (2010). *Air Quality Effects of Urban Trees and Parks*. 48.